Comparison of Different Calibration Approaches in S-NPP CrIS Full Spectral Resolution Processing

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Abstract

The Cross-track Infrared Sounder (CrIS) on Suomi National Polar-orbiting Partnership Satellite (S-NPP) is a Fourier transform spectrometer and provides a total of 1305 and 2211 channels in normal mode and full spectral resolution (FSR) mode, respectively, for sounding the atmosphere. NOAA operated CrIS in FSR mode on December 4, 2014 for SNPP. Based on CrIS Algorithm Development Library (ADL), CrIS full resolution Processing System (CRPS) has been developed to generate the FSR Sensor Data Record (SDR). This code can also be run for normal mode and truncation mode SDRs.

Since CrIS is a Fourier transform spectrometer, the CrIS SDR need to be radiometrically and spectrally calibrated. The current calibration approach does the radiometric calibration first, and then applies the correction matrix operator (CMO), which includes the post calibration filter, spectral resampling, self-apodization removal and residual instrument line shape (ILS) removal, to the spectral calibration. In order to select the next calibration algorithm for JPSS-1, four different calibration approaches are being implemented in the ADL full resolution code. In this study, comparison results from different calibration approaches are presented and the ringing effect observed in CrIS unapodized spectra are discussed.
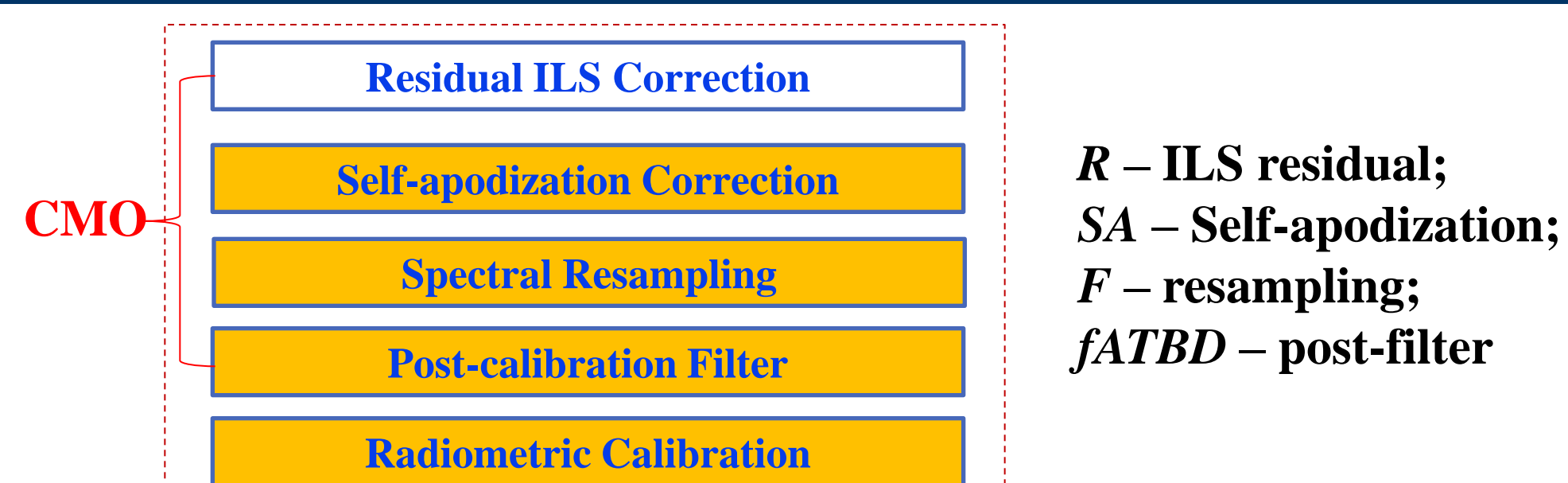
CrIS FSR Processing System (CRPS)

- The FSR ADL code is based on the IDPS Block 2.0, Mx8.5
- The resampling matrices always follow the laser metrology wavelength; in other words, they are recomputed for each neon calibration
- The CMO matrices are applied to the NEdN calculations
- Different calibration approaches are implemented in the code in order to study the ringing effect observed in CrIS normal mode SDR and to support to select the best calibration algorithm for J1
- Code is modularized and flexible to run different calibration approaches
- The same source code can be compiled into normal-resolution executable or FSR executable:

Same source code

Normal-resolution RDRs or FSR RDRs → Normal-resolution executable → Normal-resolution SDRs

FSR RDRs → FSR executable → FSR SDRs
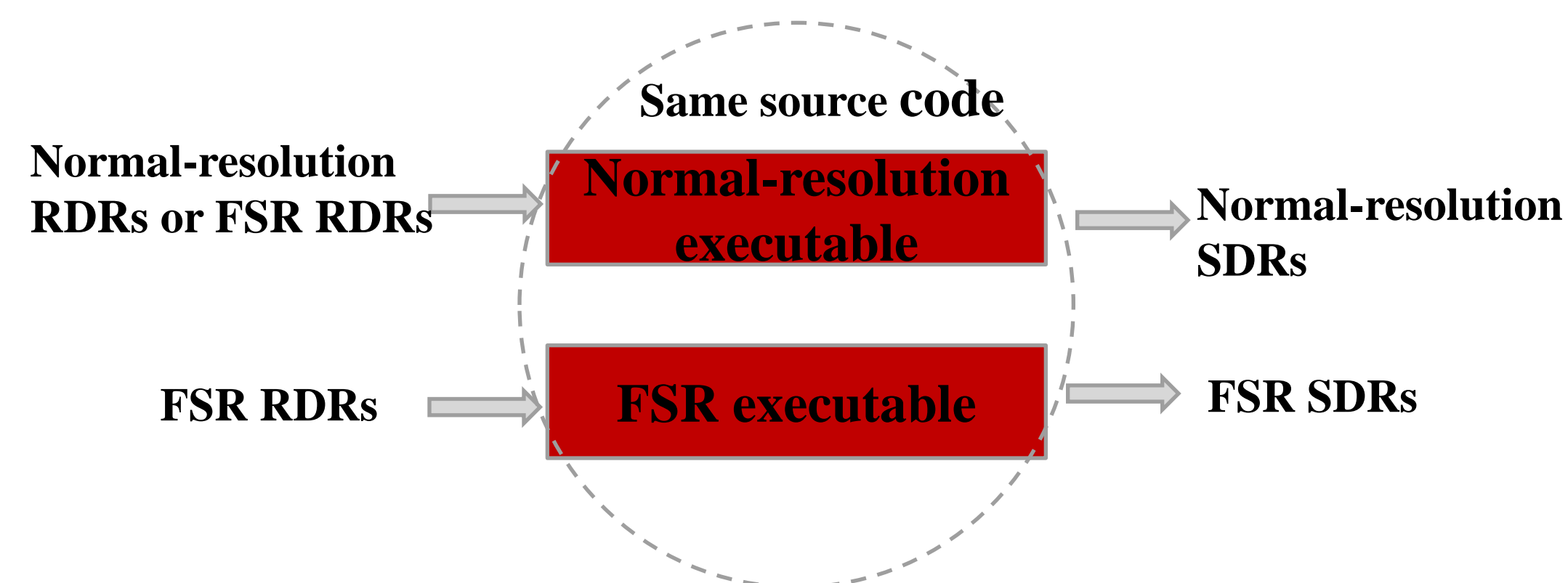
- CrIS SDR Algorithm product comprises the radiance, NEdN (noise), geolocation, and data quality flags (Han et al 2013). The FSR SDRs data are available to the public with a data latency of about 24 hours on two sites:
  (1) STAR FTP site (refresh in 7 days): ftp://ftp2.star.nesdis.noaa.gov/smcd/xxiong/
  (2) GRAVITE (refresh in 34 days): https://gravite.jpss.noaa.gov/ (need a GRAVITE account)

Calibration Approaches

CMO: Residual ILS Correction / Self-apodization Correction / Spectral Resampling / Post-calibration Filter / Radiometric Calibration

R – ILS residual;
SA – Self-apodization;
F – resampling;
$fATBD$ – post-filter

- Four calibration equations based on recommendation from CrIS science team are implemented in the CRPS
- An index in the ADL PCT file (configuration file) configures the code for a particular calibration equation

Calibration approaches supported by CRPS

Calibration algorithm 1 (the **baseline algorithm** delivered on January):

$$S_{Cal} = SA^{-1} \cdot F \cdot f_{ATBD} \cdot \{ \frac{S_e - <S_{SP}>}{<S_{ICT}> - <S_{SP}>} ICT \}$$

SA^{-1} – computed with the large N and expansion factor 1.4 (LW), 1.6 (MW) and 2 (SW)
F – resampling matrix computed with large N
f – post-filter

Calibration algorithm 2 & 3: (proposed algorithm 2 in Mooney, D. (2014) algorithm list)

$$S_{Cal} = ICT \frac{F \cdot f_{ATBD} \cdot SA^{-1} \cdot f_{ATBD} \cdot FIR^{-1} \cdot (S_e - <S_{SP}>)}{F \cdot f_{ATBD} \cdot SA^{-1} \cdot f_{ATBD} \cdot FIR^{-1} \cdot (<S_{ICT}> - <S_{SP}>)}$$

Algorithm 2:
SA^{-1} – Sincq, small N
F – Mooney (small N)
f – post-filter
IFGs are centered by adding Phase to spectra

Algorithm 3:
SA^{-1} – Sincq, big N
F – Mooney (big N)
f – post-filter

Calibration algorithm 4 (proposed algorithm in Predina and Han (2015)):

$$S_{Cal} = ICT \frac{F \cdot f_{ATBD} \cdot SA^{-1} \cdot f_{ATBD} \cdot \{\frac{\Delta S_1}{\Delta S_2} |\Delta S_2|\}}{F \cdot f_{ATBD} \cdot SA^{-1} \cdot f_{ATBD} \cdot |\Delta S_2|}$$

$\Delta S_1 = FIR^{-1}(S_e - <S_{SP}>)$
$\Delta S_2 = FIR^{-1}(<S_{ICT}> - <S_{SP}>)$

SA^{-1} – Sincq, big N
F – Mooney (big N)
f – post-filter

Self-apodization matrix (SA)

Small N, (N): Number of bins after decimation	$SA[k',k] = \int_{\sigma_{min}}^{\sigma_{max}} Psinc(\frac{\sigma_{k'} - \sigma'}{\Delta \sigma_u}, N)ILS(\sigma', \sigma_k)d\sigma'$, $k=0, N-1; k'=0, N-1$	Expansion factor $\beta=1.0$ for all three bands
Big N, (N₀): Number of bins before decimation	$SA[k',k] = \int_{\sigma_{min}}^{\sigma_{max}} Psinc(\frac{\sigma_{k'} - \sigma'}{\Delta \sigma_u}, N_0)ILS(\sigma', \sigma_k)d\sigma'$, $k=0, \beta N-1; k'=0, \beta N-1$	Expansion factor $\beta=1.4$ (LW), 1.6 (MW) and 2.0 (SW), respectively

Resampling matrix (F)

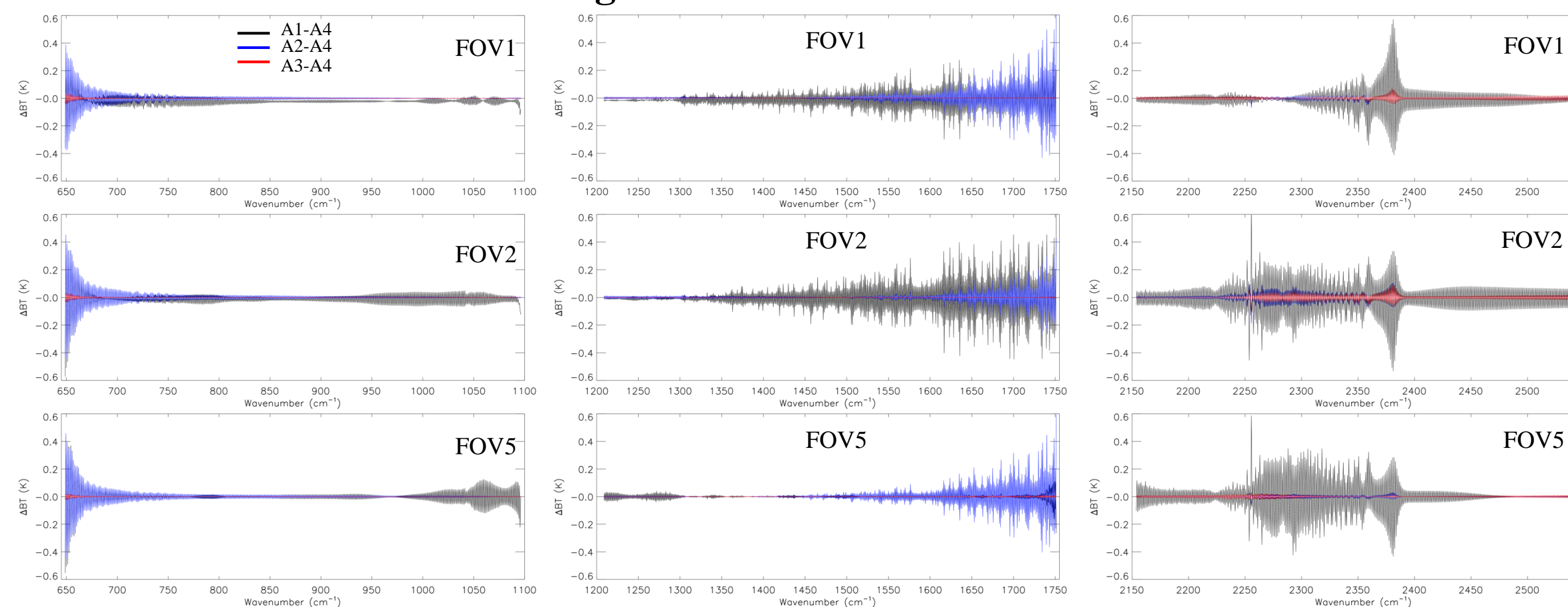| Small N, (N): Number of bins after decimation	$F[k,k'] = \frac{\Delta \sigma_s}{\Delta \sigma_u} \frac{Sin(\pi \frac{\sigma_{s,k'} - \sigma_{u,k}}{\Delta \sigma_u})}{NSin(\pi \frac{\sigma_{s,k'} - \sigma_{u,k}}{N\Delta \sigma_u})}$, $k=0, N-1; k'=0, N-1$
Big N, (N₀): Number of bins before decimation	$F[k,k'] = \frac{\Delta \sigma_s}{\Delta \sigma_u} \frac{Sin(\pi \frac{\sigma_{s,k'} - \sigma_{u,k}}{\Delta \sigma_u})}{N_0 Sin(\pi \frac{\sigma_{s,k'} - \sigma_{u,k}}{N_0 \Delta \sigma_u})}$, $k=0, N-1; k'=0, N-1$

SDR Radiance Direct Comparison Results

LW sweep direction differences (ringing) $(BT_{obs})_{fwd} - (BT_{obs})_{rev}$

A1   A2   A3   A4
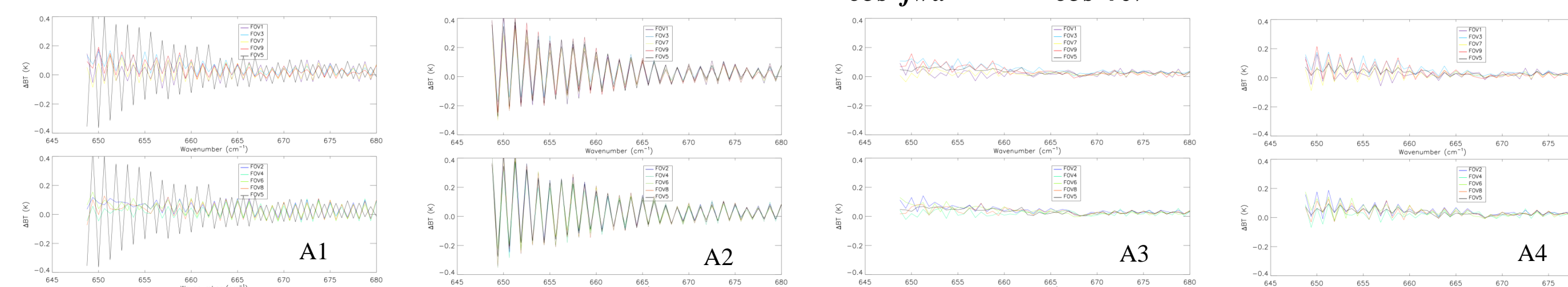
Mean BT difference between algorithms


A1-A4, A2-A4, A3-A4
FOV1, FOV2, FOV5

- Algorithms 3 and 4 significantly reduce the sweep direction differences especially for FOV 5 at the beginning edge of band 1; larger ringing artifacts are showed in Algorithms 1 and 2
- The mean BT differences between other algorithms and algorithm 4 show: For LW, Algorithm 1 has larger difference at the both band edges; Algorithm 2 only has large difference at the beginning of the band edge. For MW, Algorithms 1 and 2 have larger differences towards the end of band. For SW Algorithms 1 has larger differences at the coldest lines and regions. For all bands, Algorithm 3 is basically the same as Algorithm 4.

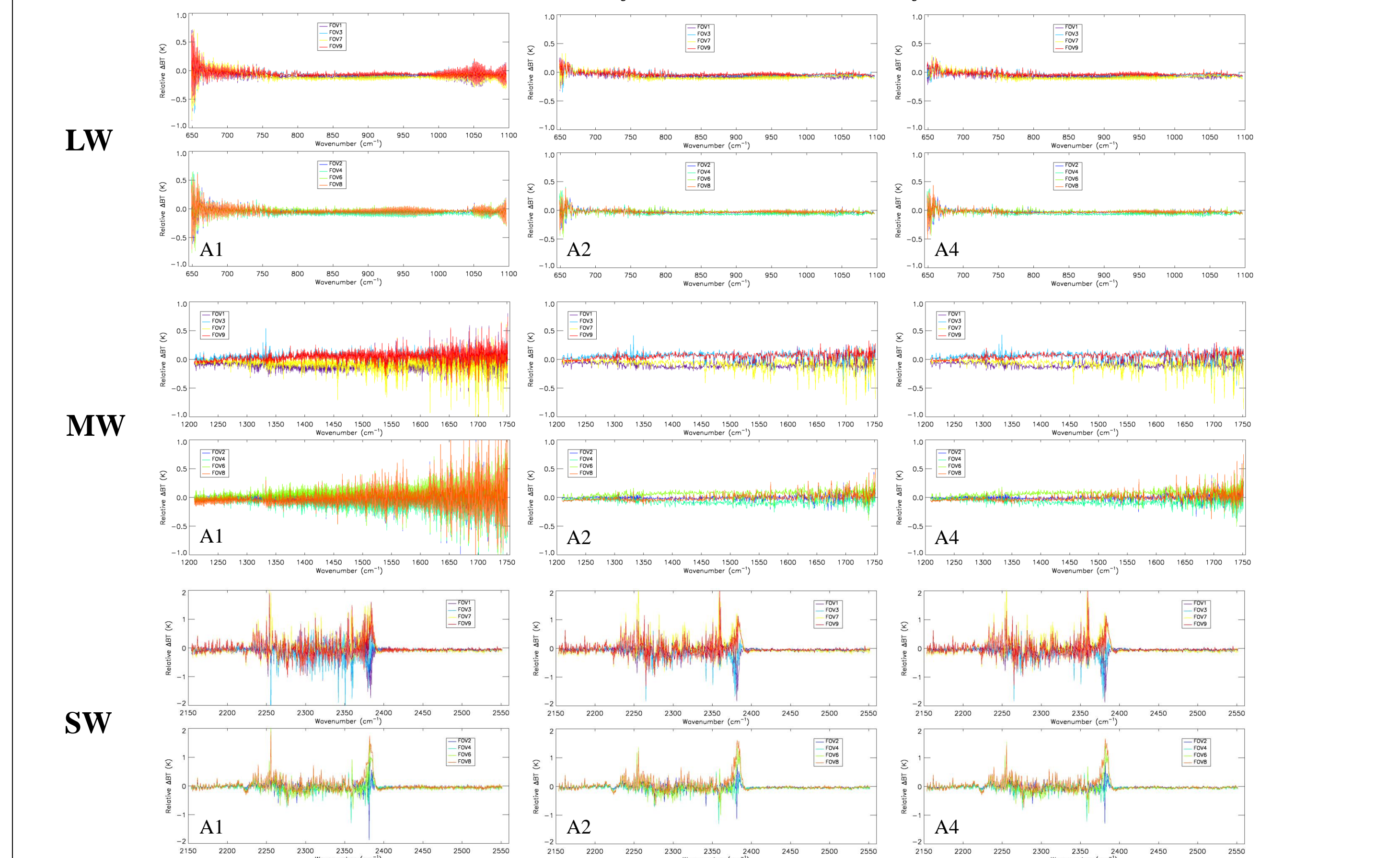---

SDR Radiance Compared with LBL Simulation

Sweep direction differences (ringing) $(BT_{obs} - BT_{lbl})_{fwd} - (BT_{obs} - BT_{lbl})_{rev}$

A1   A2   A3   A4
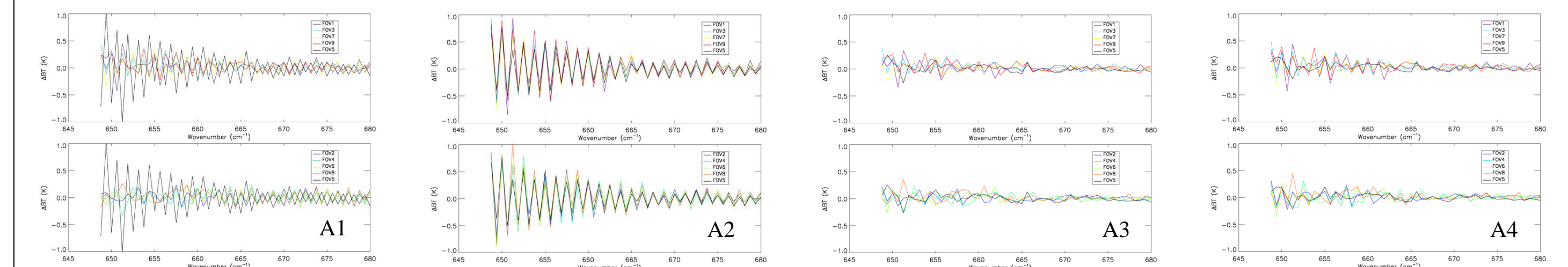
Calibration bias using LBLRTM simulation $BT_{obs} - BT_{lbl}$

FOV5, FOV1, FOV2
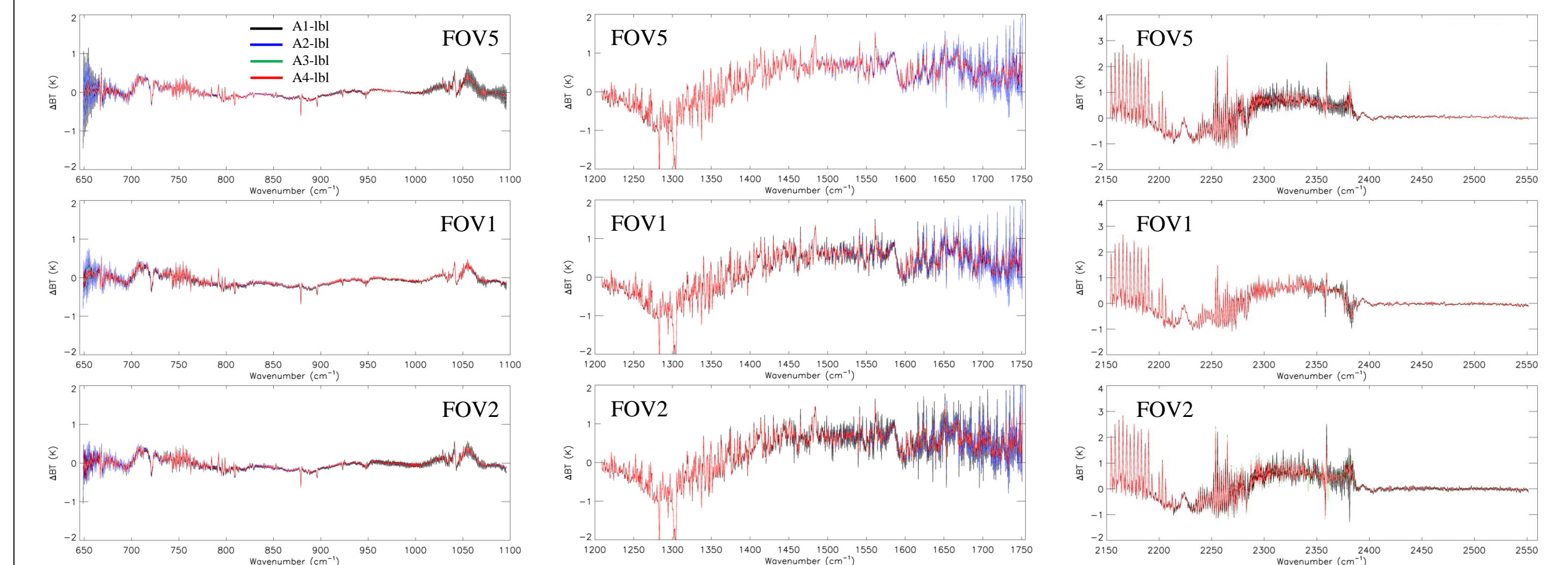
FOV-2-FOV comparison $(BT_{obs} - BT_{lbl})_{fov\_i} - (BT_{obs} - BT_{lbl})_{fov\_5}$

LW

A1   A2   A4

MW

A1   A2   A4

SW

A1   A2   A4

- CrIS SDR algorithm comparisons using FSR CrIS data and LBL simulation show that Algorithms 3 and 4 are the best choice in term of absolute bias, sweep direction difference (ringing artifact) reduction, and FOV-2-FOV consistence

Conclusion

- In this study, we have implemented different calibration approaches in the CrIS full resolution SDR code in order to study the ringing effect observed in CrIS unapodized spectra and to support to select the best calibration algorithm for J1
- Results show Algorithms 3 and 4 are the best choice in term of absolute bias, sweep direction difference (ringing artifact) reduction, and FOV-2-FOV consistence
- Based on these results, we strongly recommend that Algorithm 4 as the J1 calibration algorithm to implement into J1 CrIS code since Algorithm 4 is more computationally efficient than Algorithm 3

References and Acknowledgments

- Han, Y., et al. (2013), Suomi-NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality, J. Geophys. Res. Atmos., 118, doi:10.1002/2013JD020344
- Mooney, D. (2014), CrIS Calibration Equation, STAR JPSS Annual Science Team Meeting, May 12-16, 2014, College Park, MD
- Predina, J. and Han, Y. (2015), Alternate CrIS SDR Algorithm Flows. February 25, 2015, CrIS SDR Science Team meeting